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Using Globular Clusters to Test Newtons Law of Gravity

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Abstract. New measurements of the velocity dispersion of the globular cluster ω Centauri allow to trace its gravitational potential down to an acceleration of 8×10^{-9} cm s^{-2}. It is found that the dispersion profile remains flat well inside the tidal radius as soon as the acceleration of gravity approaches a_0, a result that finds its simplest explanation within the contest of MOND. A similar behavior is observed in the globular cluster M15 showing this is not a peculiar features of ω Centauri. This result is surprising and suggestive of a failure of Newton's law at low accelerations.

1. Introduction and Discussion

We present the results of a study of the kinematics of the external regions of ω Centauri and M15, a work triggered by the increasing evidences that Newtons law of gravity may not apply to acceleration smaller than $a_0 = 1.2 \times 10^{-8}$ cm s^{-2} (Begeman et al. 1991), as proposed within the contest of the modified Newtonian dynamics (MOND; Milgrom 1983). We focused on globular clusters because they are believed to be dark matter free and hence should agree precisely with Newtons law at any acceleration. Interestingly, in ω Centauri the velocity dispersion does not show the typical Keplerian falloff remaining constant at large radii (Fig. 1). It is worth to point out that assuming a mass to light ratio M/L=1 in solar units, appropriate for globular clusters as suggested by dynamical study (Mandushev et al. 1991), it turns out that the dispersion flattens for $a = 2.1 \pm 0.5 \times 10^{-8}$ cm s^{-2}, similar to a_0. A similar set of data for M15 (Drukier 1998) shows that also in this globular cluster the velocity dispersion profile remains flat (within errors) at large radii (Fig. 1). The flattening of the velocity dispersion occurs for $a = 1.7 \pm 0.6 \times 10^{-8}$ cm s^{-2}, again similar to a_0.

Though it is conceivable the observed flattening of the velocity dispersion profile is due to either tidal heating or to a massive dark matter halo surrounding the clusters, both scenarios require ad hoc assumptions to make the profile flat. What is striking is that these two clusters have very little in common, having different masses, different positions and different orbits in the galactic halo. Their dynamical evolution was also different to such an extent that while M15 is a textbook example of a globular cluster, ω Centauri has been claimed to be the merger of two cluster (Lee et al. 1999) or the remnant of a dwarf galaxy (Hilker 2000). Thus we find the fact that the two profiles are so similar a significant one. Globular clusters are hundreds of times smaller and thousands of time less massive than galaxies, nonetheless the velocity dispersion profile of at least

these two clusters precisely mimics, both in shape and absolute acceleration, the one of elliptical galaxies (explained invoking dark matter; Carollo et al. 1995). There is no reason for the flattening in globular clusters and galaxies to occur for the same value of the acceleration. Therefore, our result finds its simplest explanation within the framework of MOND, supporting the suggestion that Newtons law of gravity may fail in the low acceleration limit.

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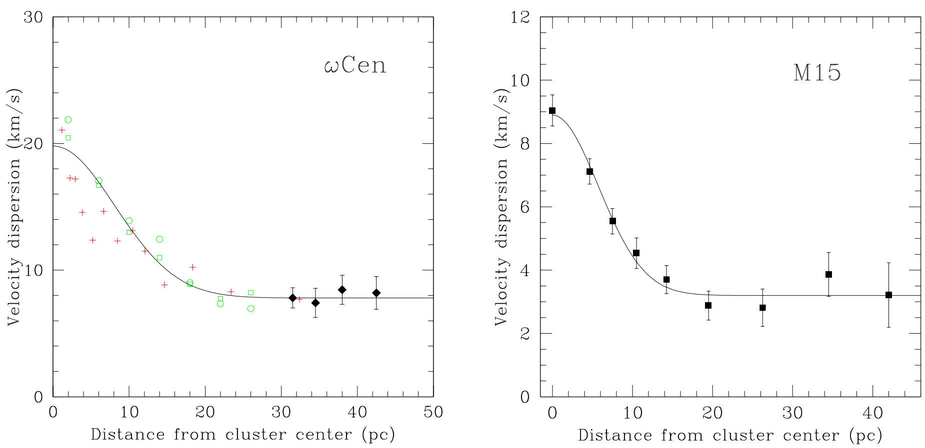

Fig 1. Left: The velocity dispersion profile of ω Centauri. Proper motion (Circles and Squares, Van Leeuwen et al. 2000) and radial velocities (Crosses, Meylan et al. 1995 and Meylan & Mayor 1986) data show the velocity ellipsoid is isotropic. Our radial velocities measurement (Diamonds) extend the profile to 45 pc showing the velocity dispersion remains constant for R> 27 ± 3 pc. **Right:** Dispersion profile of the globular cluster M15, from data by Drukier et al. (1998). Also in this case the velocity dispersion remains basically constant for R> 18 ± 3 pc. In both panel the solid line is not a fit to the data. It is meant to visualize that the velocity dispersion remains constant at large radii.